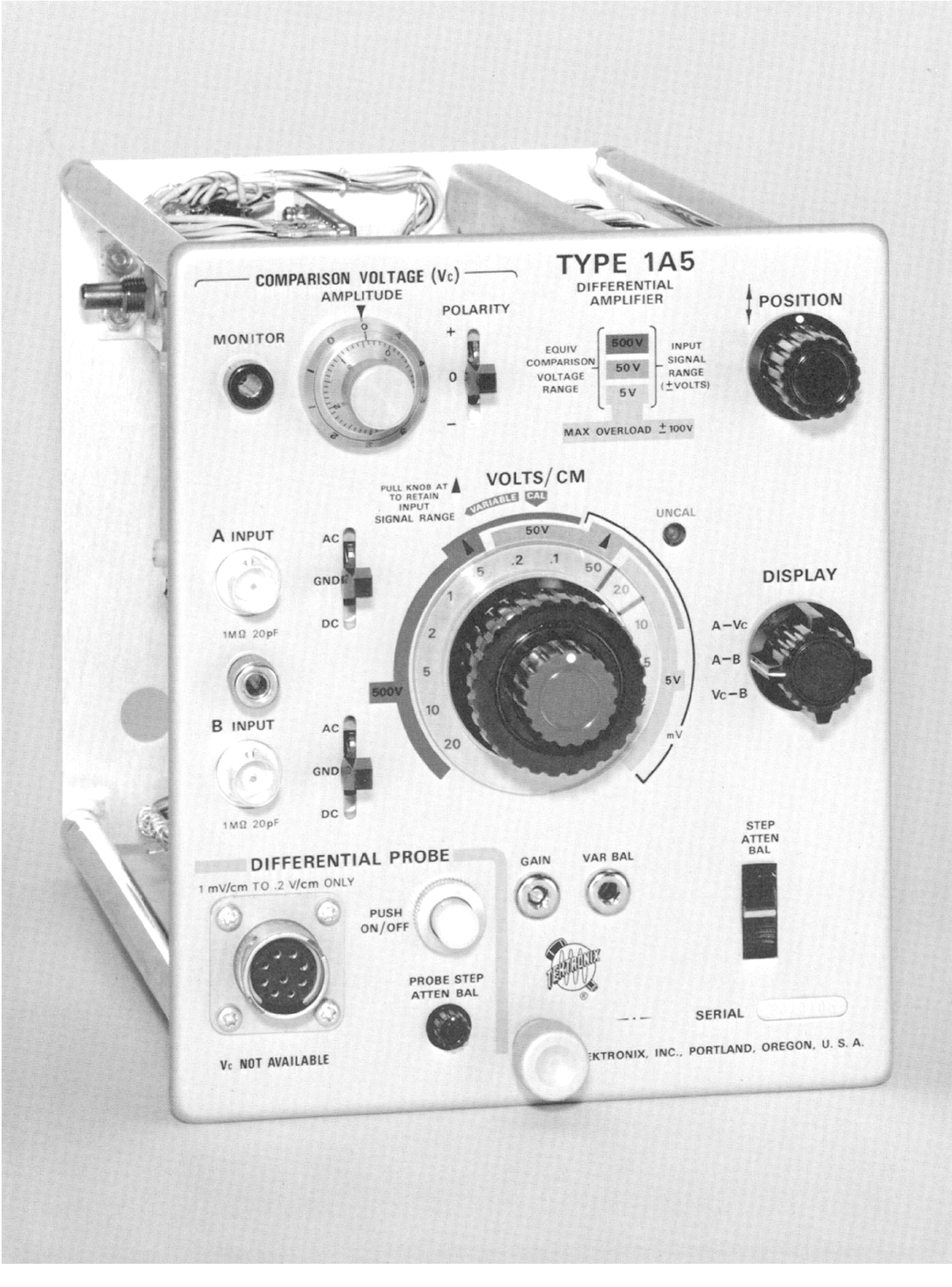
INSTRUCTION MANUAL

Serial Number ______________

TYPE 1A5 DIFFERENTIAL AMPLIFIER PLUG-IN UNIT

Tektronix, Inc.
S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon 97005 ● Phone 644-0161 ● Cables: Tektronix
070-0638-00 567


TYPE 1A5
DIFFERENTIAL AMPLIFIER
COMPARISON VOLTAGE (Vc)
AMPLITUDE
POLARITY
MONITOR
POSITION
EQUIV COMPARISON VOLTAGE RANGE
500 V
50 V
5 V
INPUT SIGNAL RANGE (± VOLTS)
MAX OVERLOAD ± 100V
VOLTS/CM
PULL KNOB AT ▲ TO RETAIN INPUT SIGNAL RANGE
VARIABLE
CAL
UNCAL
50V
500V
5V
mV
A INPUT
AC
GND
DC
1MΩ 20pF
B INPUT
DISPLAY
A−Vc
A−B
Vc−B
DIFFERENTIAL PROBE
1 mV/cm TO .2 V/cm ONLY
PUSH ON/OFF
PROBE STEP ATTEN BAL
GAIN
VAR BAL
STEP ATTEN BAL
SERIAL
Vc NOT AVAILABLE
TEKTRONIX
TEKTRONIX, INC., PORTLAND, OREGON, U. S. A.

SECTION 1
CHARACTERISTICS

Introduction

The Type 1A5 Differential Amplifier is a wide band, high gain and high common-mode rejection ratio plug-in unit designed for use in Tektronix Type 544, 546, 547 and 556 Oscilloscopes and their rackmount equivalents. It can be operated in all other 540 series and in all 530, 550 and 580 series oscilloscopes with some reduction in performance.

Flexibility is built into the Type 1A5 Differential Amplifier, in that it can be used with either passive or active probes. The active probe provision enhances the inherently high sensitivity and common mode rejection ratio features of the Type 1A5, by performing differential adding in the probe at the signal source.

Basic capabilities of the Type 1A5 Differential Amplifier (when used with an appropriate oscilloscope) include, but are not limited to, the following:

Passive Probe Inputs

Differential Amplifier Operation: Simultaneous comparison of two signals against each other to determine their algebraic difference.

Conventional Amplifier Operation: Observation and measurement of a signal by comparison against ground reference; referred to as single ended operation.

Differential Comparator Operation: Observation and measurement of a signal by comparison against a calibrated internal DC source.

Active Probe Inputs

Differential Amplifier Operation: Simultaneous comparison of 2 signals against each other to determine their algebraic difference.

Conventional Amplifier Operation: Observation and measurement of a signal by comparison against ground.

ELECTRICAL CHARACTERISTICS

Table 1-1 lists the Type 1A5 Differential Amplifier electrical characteristics. Figure 1-2 illustrates the Type 1A5 common-mode rejection ratio values given in Table 1-1 and also shows the CMRR response curve of a typical Type 1A5.

TABLE 1-1
Electrical Characteristics

Characteristic	Performance Requirement	Supplemental Information
Bandwidth DC Coupled 5 mV/cm to 20 V/cm	DC to ≥ 50 MHz at —3 dB	VOLTS/CM "Knob In" positions
2 mV/cm	DC to ≥ 45 MHz at —3 dB	Also pertains to 20 mV and .2 V Retained Range positions
1 mV/CM	DC to ≥ 40 MHz at —3 dB	Also pertains to 10 mV and .1 V Retained Range positions
AC Coupled 5 mV/CM to 20 V/CM	≤ 2 Hz to ≥ 50 MHz at —3 dB	VOLTS/CM "Knob In" positions
2 mV/CM	≤2 Hz to ≥ 45 MHz at —3 dB	Also pertains to 20 mV and .2 V Retained Range positions
1 mV/CM	≤ 2 Hz to ≥ 40 MHz at —3 dB	Also pertains to 10 mV and .1 V Retained Range positions
Transient Response Risetime 5 mV/CM to 20 V/CM	≤7 ns	VOLTS/CM "Knob In" positions
2 mV/CM	≤ 8 ns	Also pertains to 20 mV and .2 V Retained Range positions
1 mV/CM	≤ 9 ns	Also pertains to 10 mV and .1 V Retained Range positions

TABLE 1-1 (cont)

Electrical Characteristics

Characteristic	Performance Requirement	Supplemental Information
Common-Mode Rejection Ratio DC Coupled 1 mV/CM to 20 mV/CM (×1)	≥ 20,000:1, DC to 100 kHz, 0°C to 50°C ≥ 10,000:1, 100 kHz to 1 MHz, 0°C to 50°C; decreasing to ≥ 1000:1 at 10 MHz with a + and —0.5-V signal applied	See Fig. 1-1 + and —5-V signal applied
	≥ 200:1 at 20 MHz	+ and —0.25-V signal applied
10 mV/CM to 2 V/CM (×10, ×100)	≥ 2000:1, DC to 10 kHz	+ and —50-V signal applied; Applies to 10 mV/CM and 20 mV/CM only in Retained Range positions of VOLTS/CM control
5 V/CM to 20 V/CM (×1000)	≥100:1, DC to 10 kHz	
AC Coupled 1 mV/CM to 20 mV/CM (×1)	≥ 1000:1 at 60 Hz	+ and —5-V signal applied
Vertical Deflection Factor (VOLT/CM) Range	1 mV/CM to 20 V/CM in 1-2-5 sequence	
Accuracy 1 mV/CM to 20 mV/CM (×1)	±2%, 25°C within ±10°C ±2.5%, 0°C to +50°C	
10 mV/CM to 20 V/CM (×10, ×100, ×1000)	±2.5%, 25°C within ±10°C ±3%, 0°C to +50°C	
Common-mode Dynamic Range (Input Signal Range) 1 mV/CM to 20 mV/CM (×1)	≥ ±5 V DC + peak AC	
10 mV/CM to .2 V/CM (×10)	≥ ±50 V DC + peak AC	
.1 V/CM to 20 V/CM (×100, ×1000)	≥ ±500 V DC + peak AC	
DC Drift With Time Long Term	≤ 200 μV/hour at 25°C	
Short Term	≤ 200 μV/min at 25°C	
With Temperature	≤ 200 μV/°C	
With Line Voltage	≤ 300 μV (105 V AC to 125 V AC)	
DC Shift Due to Overdrive	≤ 1% of + or — overdrive signal or ≤ 10 mV, whichever is smaller	
Overdrive Recovery Time	Within 10 mV of DC shifted level after 1 μs	
Attenuator Crosstalk 1 mV/CM to 20 mV/CM	≤ 1%, DC to 50 MHz	+ and — 5-V signal applied
10 mV/CM to .2 V/CM	≤ 1%, DC to 50 MHz	+ and — 50-V signal applied (10 mV and 20 mV Retained Range positions)
Total Crosstalk	≤ 5%, DC to 50 MHz	
Noise	≤50 μV RMS	
Microphonics	≤ 100 μV	
Input Characteristics DC Resistance	1 MΩ ±0.15% (1 mV/CM to 20 V/CM)	
Time Constant	Normalized with 20 pF normalizer for ≤1% overshoot, rounding or tilt of Type 106 1 kHz square wave.	
Maximum Input Voltage 1 mV/CM to 20 mV/CM	±100 V DC + peak AC	Also applies to maximum allowable difference between A and B INPUT voltages.
10 mV/CM to 20 V/CM	±500 V DC + peak AC	Applies to 10 mV/CM and 20 mV/CM only in Retained Range positions of VOLTS/CM control.

TABLE 1-1 (cont)

Electrical Characteristics

Characteristic	Performance Requirement	Supplemental Information
Gate Current	≤ 0.1 nA at 25°C	
	≤ 1.0 nA at 50°C	
COMPARISON VOLTAGE (Vc) 1 mV/CM to 2 V/CM Range	0 V to + or − 5 V	
Accuracy	within ±5 mV or ±0.5% of indicated voltage, whichever is greater (0°C to 50°C)	
5 V/CM to 20 V/CM Range	0 V to + or − 0.5 V	
Accuracy	±1 mV or ±1% of indicated voltage, whichever is greater (0°C to +50°C)	
Control Range VARIABLE VOLTS/CM	≥ 2.5:1	
POSITION	≥ 12 cm	
STEP ATTEN BAL	≥ 20 mV (×1)	

MECHANICAL CHARACTERISTICS

The Type 1A5 Differential Amplifier is 14½ inches long, 4¼ inches wide and 6¼ inches high. It is designed to fit all Tektronix one-series plug-in compartments and is held in place by a threaded shaft connected to a front-panel knob. Ventilation for the Type 1A5 is provided by the oscilloscope ventilating system. All of the controls used in operating the Type 1A5 are accessible at the front-panel. An anodized finish is used to provide a durably attractive appearance.

ACCESSORIES

Standard accessories supplied with the Type 1A5 Differential Amplifier consist of two manuals.

The P6046 Active Differential Probe has been designed for use with the Type 1A5 Differential Amplfier. Information regarding it can be obtained from your Tektronix Field Engineer or Field Office.

Additional accessories are listed in the Tektronix, Inc., catalog.

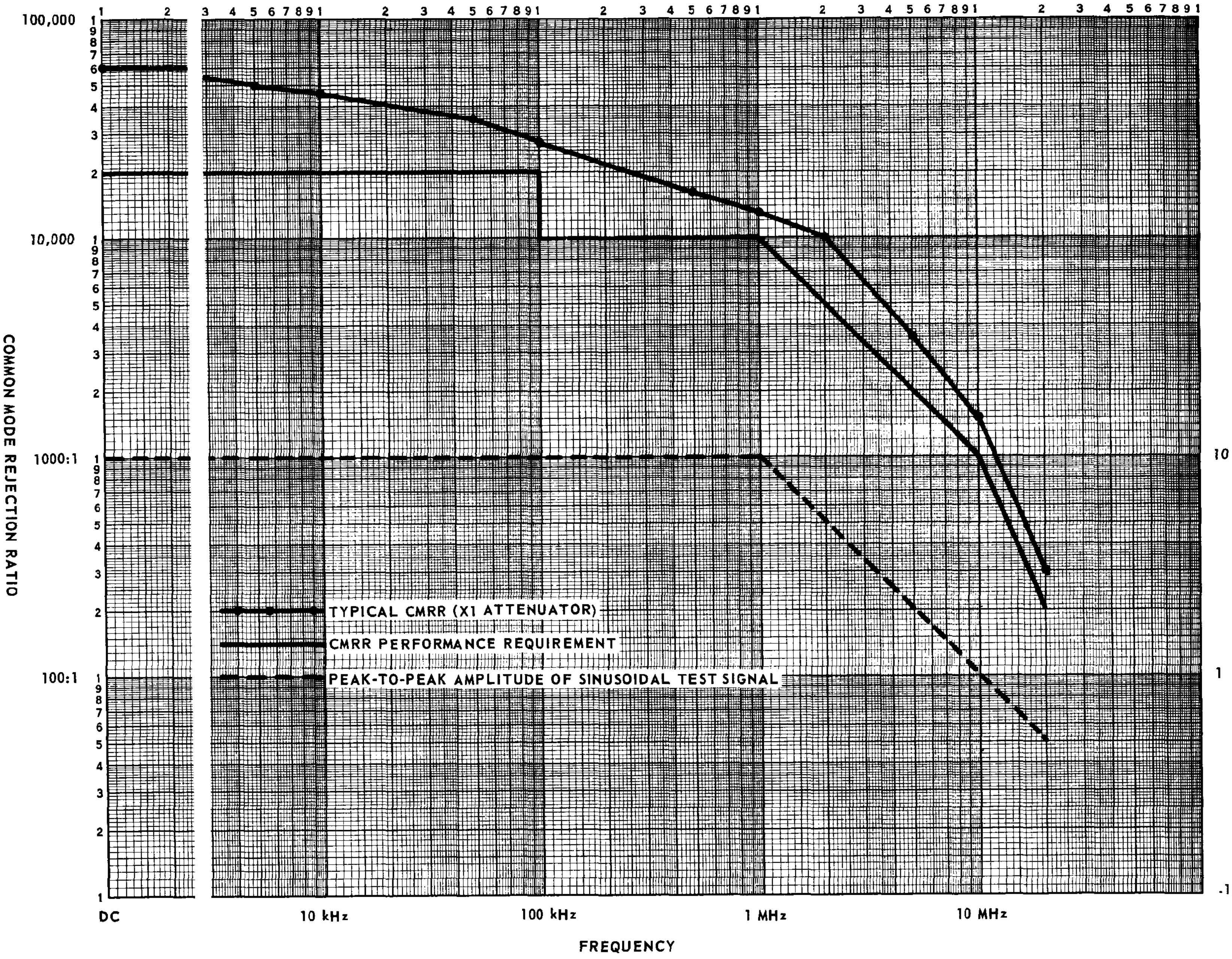


Fig. 1-2. Type 1A5 common-mode rejection ratio graph. Pertains to 1 mV/CM through 20 mV/CM sensitivities.

SECTION 3
CIRCUIT DESCRIPTION

Introduction

A detailed description of the Type 1A5 circuitry is contained in this section. The scope of coverage includes a block diagram description of overall operation, the theory of operation of individual circuits, and the functions of specific components within the circuits. This description is intended to provide enough information about the Type 1A5 to enable a technician to troubleshoot any part of it.

Simplified drawings are provided where necessary for effective circuit explanation. No attempt is made to explain basic operations of components except for those that are not general knowledge. Some additional information regarding components is included in the Maintenance Section of this manual.

Resistors on schematics are valued in ohms unless otherwise indicated. Capacitor values which are not assigned the symbol "μF" are indicated as follows: pF—whole numbers; μF—decimal numbers. Example: 0.1 is in μF; 33 is in pF.

BLOCK DIAGRAM DESCRIPTION

The Operating Instructions secion of this manual provides a block diagram and a basic description of the Type 1A5 circuitry, with emphasis on front panel controls and adjustments. It is suggested that it be reviewed before continuing in this section.

Refer to the Block Diagram in Section 9. The A channel and B channel make up most of the Type 1A5 circuitry. These two channels are identical except that a signal applied to the A channel will cause a displayed signal of the same polarity as the input signal, and a signal applied to the B channel will cause an inverted display signal. The two channels are distinct until after they enter the Comparator circuit. From there on they operate in push-pull, providing outputs to be applied to the oscilloscope vertical amplifier. If desired, signals can be accepted from an active differential probe instead of from the A INPUT and B INPUT circuitry.

Four operating voltages are developed within the Type 1A5: +20.7 and +60 volts for circuit operation; +6.2 V for reed switch and active probe operation; and a variable 5 volts for input voltage comparison purposes. In addition, +50 volts and — 50 volts are developed within the Type 1A5 for Differential Probe operation.

Assume that A-Vc has been selected by the DISPLAY switch and a Comparison Voltage of 0 is applied to the B channel.

A signal applied to the A INPUT connector passes through the Input Coupling selector switch to the Input Attenuator circuit where is is attenuated by a factor of 1, 10, 100 or 1000. The output of the selected attenuator is applied to a contact of the DISPLAY switch. From the DISPLAY switch the signal goes to the gate of field effect transistor (FET) Q123A. The output is taken from the source of Q123A and passes through emitter follower Q143 to a contact of a relay controlled by the Differential Probe PUSH ON/OFF button. Transistors Q133 and Q128 aid in the operation of the FET circuit.

If Differential Probe operation has not been selected, a relay routes the signal to Q164 in the Comparator circuit. The Comparator acts as a paraphase amplifier which provides a push-pull output in response to signals from either the A channel or the B channel. With a signal applied, Q164 provides an inverted output through V164 and emitter-follower Q183 to gain switching amplifier Q314-Q334. Responding to the same signal into Q164, the other half of the Comparator (Q264, V264 and Q283) provides Q324-Q344 with a signal having a polarity opposite to that applied to Q314.

The amount of amplification provided by the Gain Switching Amplifier (Q314-Q324) is controlled by the VOLTS/CM control. The Output Amplifier further amplifies the push-pull signal from Q314-Q324 and provides an output which is impedance-matched to the oscilloscope's vertical amplifier circuit.

Returning to the Comparator circuit, if the Comparator receives signals simultaneously from the two input channels, its output will be an amplification of the difference between the two. Therefore, if the two signals are equal in amplitude and phase (common-mode), the Comparator will have no signal output. In A-B mode, this "differential amplifier" action occurs and provides an output which is representative of the difference between the signals applied at the A and B INPUT connectors.

With the DISPLAY switch in A-Vc or in Vc-B position, the COMPARISON VOLTAGE (Vc) network can be used to supply a voltage to one of the signal channels. The Comparator will accept this as a DC signal, and will cancel an equal amount from the signal in the other channel.

When the Differential Probe signal is selected by depressing the PUSH ON/OFF button, a push-pull signal goes from the probe to the Comparator. The Comparator then acts as a conventional push-pull amplifier.

Power Supplies. The Type 1A5 receives the following voltages from the oscilloscope: +225 V, +100 V, +75 V, —150 V DC, and 6.3 V AC. Circuits within the Type 1A5 provide four additional regulated voltages for Type 1A5 operation. The +20.7 and +6.2 volt supplies are located on the Input Amplifier board and use the +75-V input as their source. An adjustable +60-V supply, located on the Output Amplifier board, is powered by the +100-V input. A COMPARISON VOLTAGE (Vc) supply is derived from the +100-V or —150 V input and can be either + or —5 V as determined by the POLARITY control. The Differential Prove is powered by the +6.2/+20.7-V supply and by +50-V and —50-V supplies derived from the +60-V and —150-V supplies respectively.

DETAILED CIRCUIT DESCRIPTION

Input Circuitry

This explanation of the A Input circuitry can be adapted to the B Input circuitry, since the two are essentially identical.

Input Coupling

The Input Amplifier schematic shows the A Input Coupling circuit, which includes J101, C101, R101 and SW101. Input signals pass through J101 and connect to coupling capacitor C101 and the DC terminal of Input Coupling switch SW101. C101, SW101 and R101 form a combination input coupling and precharge-discharge circuit. With SW101 connected to the GND terminal, the A amplifier channel input is grounded and C101 charges through R101 to the DC value of the input signal. When SW101 is subsequently switched to the AC position, the amplifier is not disturbed by any DC charging current.

Under AC input coupling conditions, C101 retains its DC charge after the input signal is removed. It can be discharged safely through R101 by placing SW101 to the DC position.

C101 and the B Input channel's C201 are matched to within 1% to ensure at least 1000:1 CMRR at 60 Hz.

Attenuators

Matched attenuators are simultaneously inserted into the A and B INPUT signal paths by the VOLTS/CM switch. The ×1, ×10, ×100 and ×1000 attenuators divide the input signal by the indicated factor and also control the Input Signal Range and the Maximum (non-destructive) Input Voltage for the Type 1A5. The VOLTS/CM switching schematic shows details of the switching and attenuator circuitry, and Table 3-1 lists the attenuator in use in each switch position.

The ×10, ×100 and ×1000 attenuators consist of RC voltage dividers which combine with the remaining input circuitry to provide the indicated fractional output to the gates of Q123. (The ×1 attenuator provides a direct path through the attenuator unit and therefore involves no components.) Resistor tolerances are 0.1% and provide low frequency attenuation accuracy of 0.2% in single-ended operation. Attenuation accuracy at higher frequencies is obtained by using adjustable capacitors.

Matching between the A and B Input Attenuators is obtained by adjusting one to the other after attenuation accuracy has been obtained. A DC common-mode rejection ratio of 2000:1 is obtained with the ×10 and ×100 attenuator in use by adjusting R105D and R106D respectively. The AC common-mode rejection ratio for ×10 and ×100 attenuator operation is obtained by adjusting C205D and C206B. Table 3-2 lists all the attenuator circuitry adjustments and their purposes.

TABLE 3-1

VOLTS/CM Switch Selection Data

VOLTS/CM POSITION		Input Signal Range[1]	Attenuator in Use				Reed Switches Actuated			
Knob In	Knob Out (Retained Range)		×1	×10	×100	×1000	K301	K304 K305	K307	K311 K313
1 mV		5 V	x				x	x		
2 mV		5 V	x					x		
5 mV		5 V	x						x	x
10 mV		5 V	x							x
	10 mV	50 V		x			x	x		
20 mV		5 V	x							
	20 mV	50 V		x				x		
50 mV		50 V		x					x	x
.1 V		50 V		x						x
	.1 V	500 V			x		x	x		
.2 V		50 V		x						
	.2 V	500 V			x			x		
.5 V		500 V			x				x	x
1 V		500 V			x					x
2 V		500 V			x					
5 V		500 V				x			x	x
10 V		500 V				x				x
20 V		500 V				x				

[1]Also applies to Equivalent Comparison Voltage Range

TABLE 3-2

Input Attenuator Adjustments

Purpose Of Adjustment	Adjustments							
	"A" Input Attenuators				"B" Input Attenuators			
	×1	×10	×100	×1000	×1	×10	×100	×1000
Input Capacitance	C108	C105A	C106A	C107A	C208	C205A	C206A	C207A
H.F. Attenuation		C105B	C106B	C107B		C205B	C206B	C207B
L.F. CMRR		R105D	R106D					
H.F. CMRR						C205D	C206B	

The output of the attenuator circuit develops across R108, C108, R121, C122 and R122. C108 adjusts the input capacitance to 20 pF. C122 also affects the input capacitance, but is adjusted primarily to improve the high frequency common-mode rejection ratio. R108 and R121 form a suppression network to improve circuit stability. C109 and R109 are inserted in the signal path to improve transient response.

Source Follower and Bootstrap Circuitry

Identical source follower and bootstrap circuits are contained in the A and B channels. A simplified schematic of the A channel is presented in Fig. 3-1.

Signals passing through the input circuitry are applied to the gate of FET Q123A. (An operational analogy exists between a field effect transistor and a vacuum tube, with the gate comparing to a grid, the source to a cathode and the drain to a plate.) In typical cathode-follower manner, the signal is developed at the source of Q123A and applied to the base of emitter-follower Q143. The signal from the emitter of Q143 is applied to relay contact K295A.

The source of Q123A operates quiescently at approximately +0.6 V. This voltage is established by a relatively constant current through the high impedance source resistors R123 and R127 and constant current transistor Q128. R129 is adjusted to balance this voltage between the A and B channels during quiescence. When R129 is adjusted properly, there will be no trace shift when switching from one gain setting to another with no signal applied.

Part of the Q123A source impedance is made up of the Q143 base-emitter circuit. Resistor R141 and potentiometer R140 are placed in parallel with this circuit to allow adjustment of differences between the A and the B channel loading effects. With R140 (COMMON-MODE BAL) properly adjusted, no trace shift will result when DC or low-frequency common-mode signals within the input signal range are applied simultaneously to the A and B channels.

The bootstrap (positive feedback) circuitry consists of R148, R149 and Q133. A majority of the signal occurring at the emitter of Q143 is felt across R149 and is applied to the base of Q133. The polarity of this signal is the same as that applied to the gate of Q123A. Q133 and Q123A therefore act in unison and form a high impedance input circuit relatively independent of the gain of the active devices, and provide a gain of approximately 1 from the FET gate to the emitter of Q143.

Input Protection Circuitry

Protection from positive input signals is provided by the circuit design and D133. The high impedance source load of Q123A allows the source voltage to follow the gate signal up to +100 V without component damage. This voltage dictates the value to which the emitter of Q143 and the base of Q133 will go. As the input signal rises and the base of Q133 approaches +20 V, the collector-base junction of Q133 becomes forward biased; D133 becomes back biased. All connections to Q123A, Q133 and Q143 are allowed to rise to the vicinity of the voltage at the gate of Q123A and no stress approaching breakdown voltage exists across any components.

Negative signal input protection up to —100 V is obtained through B122, R138, R139 and Q137. During normal operating conditions, Q137 is saturated and has about 0.2 V dropped across it. The voltage at its base is approximately +21 V. When the signal on the gate of Q123A reaches about —60 V, B122 ionizes and maintains approximately 55 V across itself. This places the base of Q137 near —5 V, forcing its emitter to follow. Any further change in gate voltage will be transferred directly to Q137, keeping the difference in voltage between Q123A source and Q137 emitter within component breakdown values.

Refer back to the Input Amplifier schematic to follow the discussion of the remaining components in the A channel source-follower circuit.

Input cross-talk (inter-action) at high frequencies through the capacitance of de-ionized neon tubes B122 and B222 is kept to a minimum by decoupling action of C139. C126 (in the base biasing network of Q128 and Q228) minimizes cross-talk between the constant current circuits. C124 and C148 improve high frequency response. The series combination of C132 and R132 provides high frequency damping. The source and emitter circuit capacitances of Q123A and Q143 are set for optimum CMRR in the 1 to 10 MHz range by adjusting C123. Resistor R145 is shunted by C144 to improve the gain of Q143 at high frequencies. R159, R259 and PROBE STEP ATTEN BAL R158 allow balancing of the A and B channels during active probe operation.

B channel operation can be followed by relating the components in the B channel to their counterparts in the A channel.

Comparator Circuit

The comparator is made up of two cascaded, emitter-coupled amplifiers with a gain of about 4. It provides a push-pull output in response to any unbalance of inputs at TP160 and TP260. This unbalance can be the result of a signal input from one channel or the difference between the signals from the two channels.

Under quiescent conditions, each half of the comparator is receiving half of the current being supplied by the constant current circuit including R170, R171, R271, Q174, R174, R175 and R176. If a positive signal is received by one half of the comparator, current through it will increase. The additional current is obtained from the constant current source by decreasing the current through the other half of the comparator.

A positive signal at TP160 causes current through Q164 (and therefore through load resistor R168) to increase, resulting in a negative signal at the plate of V164. The increase of current through Q164 is obtained through R167 by decreasing current through the Q264-R268 circuit. This results in a positive signal at the plate of V264.

Ideally, if common-mode signals arrive at TP160 and TP260, the trans-impedance of the two halves of the comparator remain balanced to each other. The constant current circuit prevents any change of current in either half, and no signal output can result. Under actual common-mode signal conditions, the constant current circuit cannot

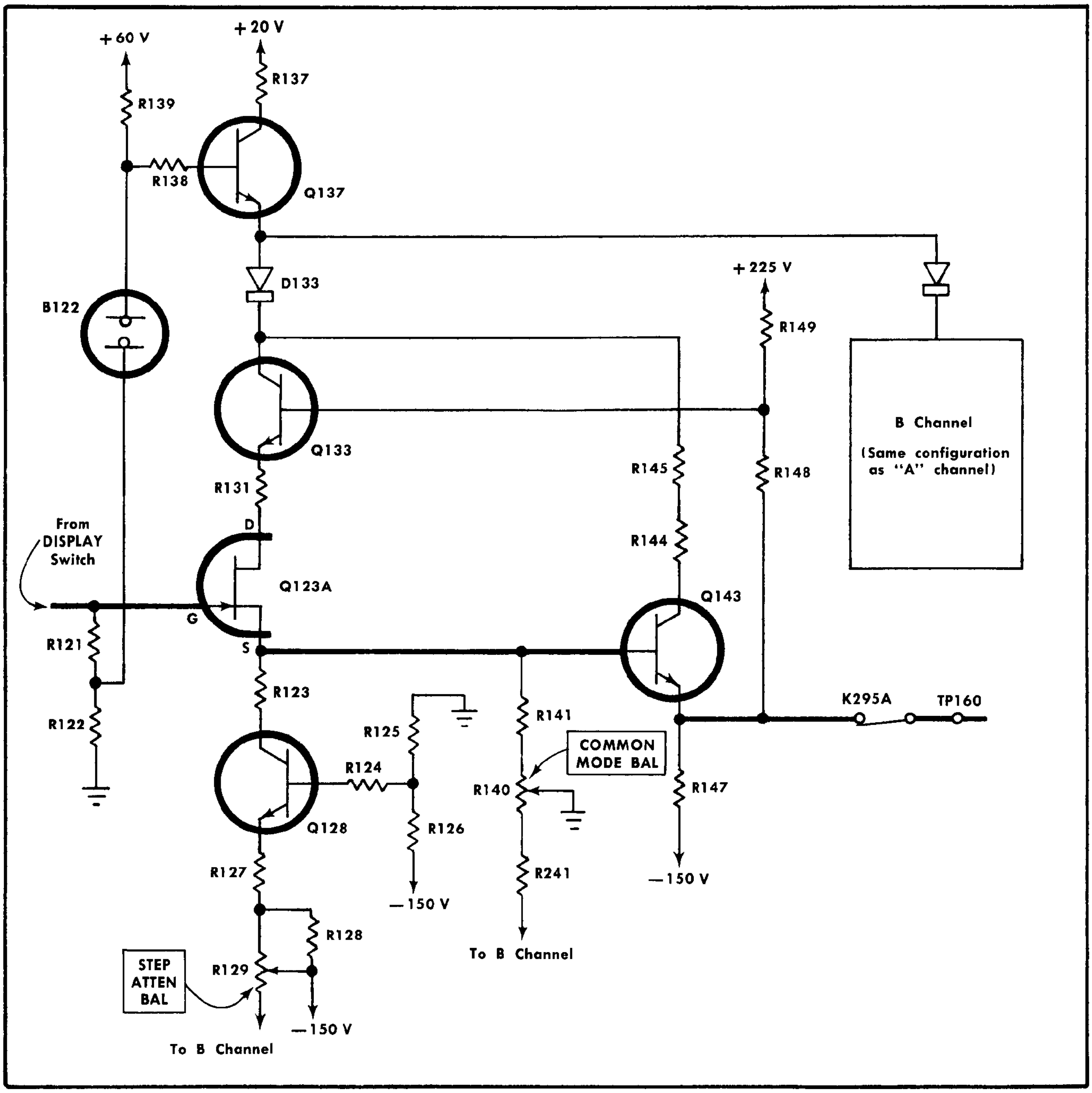


Fig. 3-1. "A" Channel Source Follower circuit, simplified.

maintain 100% constant current, but it keeps changes to a minimum. The minor changes which occur at the plates of V164 and V264 are equal and, being common-mode, will have no effect upon trace deflection.

R179, C179, R279 and C279 are bootstrapping components which help in minimizing these minor common-mode current changes through Q164 and Q264. As was previously explained, the emitter of Q133 follows the gate voltage of Q123A. AC voltage changes at Q133 emitter are coupled through R179 and C179 to the collector of the comparator constant current transistor, Q174.

The change at the collector of Q174 is therefore of the same polarity and virtually the same amplitude as that occurring at the emitter of Q164. Changing both values by the same amount in the same direction results in no change in the voltage drop across R170 and R171, and the current through them remains constant.

If identical signals are applied to both the A and B channels, the emittters of Q164 and Q264 will remain at equal voltages. The two sides of the comparator circuit are then in balance and no current will flow through R167.

The resultant constant current through R170 and R171 is the same current that flows through R168. With no change in current through R168, the voltage drop across it cannot change and the output of the amplifier remains constant. This same effect occurs in the B side of the comparator.

If any inequality exists between the signals into the two channels, the voltages at the emitters of Q164 and Q264 will not be at equal levels. Current will flow across R167, resulting in an increase of current through one transistor and a decrease through the other, causing the previously described push-pull reaction.

D167A and D167B are a matched pair of diodes which provide overload protection for the comparator circuit. They are packaged as a single unit for thermal balance. Under overload conditions, the input source-follower and emitter-follower are allowed to follow the input signal voltage in a positive or negative direction. This voltage is coupled into TP160 and TP260, and under extreme conditions would cause the breakdown voltages of components to be exceeded. D167A and D167B become reverse biased and isolate the two halves of the comparator from each other before breakdown values are exceeded. In addition to providing protection, D167A and B improve recovery time for the Type 1A5.

T167A and B improve transient response for the comparator circuit by providing instantaneous coupling of high-frequency signals from one half of the comparator to the other. V164 and V264 decrease the operating voltage across Q164 and Q264 and respond in step with them. R164, R165, R166, R264, R265 and R266 are biasing and signal coupling components for V164 and V264.

Coarse balancing of the Type 1A5 is done through DC BAL potentiometer R170. This internal adjustment acts the same and is accomplished in much the same manner as the STEP ATTEN BAL.

Transient response is improved through R169, C169, and C269. C267 adjusts the high-frequency common-mode rejection ratio of the comparator stage; C163 and C263 allow for balancing of the input capacitance to it. Decoupling of the constant current transistor's base through C176 improves circuit stability. Emitter-followers Q183 and Q283 lower the output impedance of the comparator circuit to allow efficient transmission of the signal to the Output Amplifier board and to provide impedance matching to the gain switching stage. R181 and R281 suppress parasitic oscillations which could occur if the transistors were connected directly to the +60-V supply.

Output Amplifier Circuitry

The Output Amplifier section consists of the gain switching amplifier and output amplifier circuitry.

Gain Switching Amplifier

Refer to the Output Amplifier schematic in Section 9. The A and B Gain Switching Amplifiers receive equal and opposite signals from the Input Amplifier board and, except for polarities, respond in a manner identical to each other. The Q314-Q334 amplifier section will be discussed here.

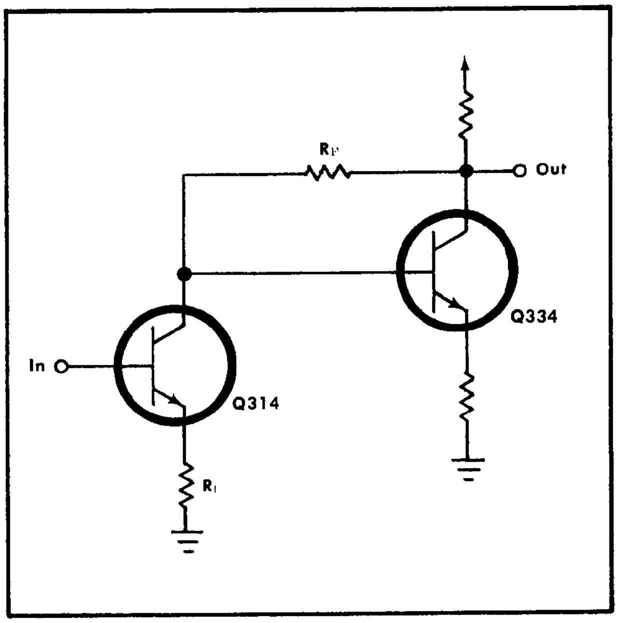


Fig. 3-2. Gain Switching Amplifier, simplified.

The simplified version of the Q314-Q334 amplifier circuit shown in Fig. 3-2 can be recognized as an operational amplifier. R_I represents the gain switching resistors in the emitter circuit of Q314 and R_F represents R333.

With a positive change of voltage at the Q314 base, an almost identical change occurs at the Q314 emitter. Current will increase through the transistor by an amount equal to the voltage change divided by R_I. ($\frac{\Delta e_{in}}{R_I} = \Delta i_{R_I}$). The majority of this current increase will flow through Q314 collector circuit and the collector voltage will attempt to drop due to normal transistor action. As the collector voltage of Q314 attempts to drop, Q334's emitter current decreases. A voltage rise occurs at the collector of Q334 and current through R_F increases by an amount equal to the change of Q334 collector voltage divided by R_F. $(\frac{\Delta e\ out}{R_F} = \Delta i_{R_F})$. When Δi_{R_F} equals Δi_{R_I} the circuit is balanced at the new operating level.

Because of Q334's amplification factor, the voltage at the base of Q334 changes by an insignificant amount and this point can be referred to as a virtual ground. The change of voltage that must occur at Q334 collector with respect to the voltage change at Q314 base is the circuit gain.

The change that occurred at the base of Q314 also occurred at its emitter and $\frac{\Delta e\ in}{R_I} = \Delta i_{R_I}$. The change at the Q334 collector resulted in a current change through R_F to balance the circuit and $\frac{\Delta e\ out}{R_F} = \Delta i_{R_F}$. Since $\Delta i_{R_I} = \Delta i_{R_F}$, it is logical to say $\frac{\Delta e\ in}{R_I} = \frac{\Delta e\ out}{R_F}$. Revising the equation results in $\frac{\Delta e\ out}{\Delta e\ in} = \frac{R_F}{R_I}$. Since $\frac{\Delta e\ out}{\Delta e\ in}$ is circuit gain, the ratio of $\frac{R_F}{R_I}$ must also equal circuit gain.

In response to signal inputs, the emitters of Q314 and Q324 always change equal amounts in opposite directions. A point midway between the resistances connecting the two emitters sees no change and represents AC ground. R_I of the Q314-Q334 operational amplifier therefore equals one-half of the resistance between the emitters of Q314 and Q324 under any switching condition.

R_F of the operational amplifier is R333, the resistance between the collector of Q334 and its base; the point of virtual AC ground.

Since an increase of current through the A amplifier is accompanied by a decrease through the B amplifier, R317 and R327 provide a constant current for the operation of the two amplifiers under all signal conditions.

VAR BAL potentiometer R330 and resistors R331 and R341 provide an adjustable amount of current to the two amplifiers to allow balancing of the following stages. When R330 is properly set, changing gain by rotating the VARIABLE control (R350) will have no effect upon the trace position under "no signal" conditions.

Circuit stability is aided by oscillation damping components C300, R300, L337[2], R336, R346 and C338. The numerous capacitors and inductors in the emittter gain switching circuitry are frequency compensating components.

Reed switches are used to control the emitter resistance for gain switching. In some instances, pairs of contacts are used to insert a single circuit. This is done to keep emitter circuit capacitance as low as possible. Table 3-1 lists the switches actuated in each VOLTS/CM switch position. The value of emitter to emitter resistance and the gain factor of the gain switching amplifier circuit in the five basic deflection factor settings are outlined in Table 3-3.

[2]L337 and numerous other "L" designated components within the Type 1A5 are not conventional coils. They are constructed by passing a wire (it may be a component lead) through the center of a ferrite core. The core is referred to as a "ferrite bead" on the schematic diagrams.

TABLE 3-3

Gain Switching Amplifier

VOLTS/CM	1 mV	2 mV	5 mV	10 mV	20 mV
Emitter-to-Emitter Resistance	135 Ω	289 Ω	761 Ω	1576 Ω	3360 Ω
Gain of Stage (Approx)	6	3	1.2	0.6	0.3

Output Amplifier

Q354, Q374 and associated components form the A Channel Output Amplifier circuit for the Type 1A5. This amplifier is essentially the same as the gain switching amplifier and the function of most of the components can be determined by comparison against that circuit. L375 and C375 are oscillation damping components. Type 1A5 gain calibration is set by adjusting GAIN potentiometer R360 with the VARIABLE control detented at 0 resistance. The gain of the Output Amplifier circuit is set to approximately four, and decreases to about 1.6 when R350 is totally inserted. UNCAL lamp B355 indicates whenever R350 is not detented.

Position Range potentiometer R370 is an internal adjustment for balancing the operation of Q374 and Q384. This adjustment is in parallel with the front panel POSITION control and therefore provides for equal range of the POSITION control above and below the graticule center. High frequency compensation is provided by T389, C378, C379, C389, R379 and R389. Adjustable components are set in the 20 mV/cm sensitivity range. R378 and R388 correct the output impedance for compatibility with the oscilloscope vertical amplifier.

Comparison Voltage

The comparison Voltage circuitry is shown on the Input Amplifier schematic. A positive or negative 9 volts, (dependent on the POLARITY switch position), is regulated by Zener diode D111 and is applied to the voltage divider consisting of R113, R114 and R115. R113 (Vc Cal) is adjusted to provide 5 V (±2.5 mV), across R115. The 10-turn Helipot AMPLITUDE control, RII5, determines how much voltage is available for application to the selected FET gate. Its dial can be read to 3 significant digits. R116 is a ground loop current limiter. C114 filters Zener noise, and the C117-R117 combination decouples spurious voltages which may otherwise reach the FET gates.

Reed switch relay K119 is activated when the VOLTS/CM control is in the 5-V, 10-V or 20-V position. R118 and R119 then are placed in parallel with R115, and the resultant decrease in resistance causes the voltage across R115 to decrease to 0.5 V. This holds the effective Vc voltage range to 500 volts even though the ×1000 atteuator is in use. Vc ×10 Cal (R119) allows calibration of the 0.5 V.

The equivalent Comparison Voltage Range is listed in Table 3-1 for each position of the VOLTS/CM control. It is the same value as the Common-Mode Linear Dynamic Range of the Type 1A5 in all instances.

The MONITOR jack is connected to the amplifier circuit whenever the DISPLAY switch is in A-Vc or Vc-B position, regardless of the POLARITY switch setting. Only shielded cables should be connected to it when waveform observations are being made.

Operating Voltages

The Type 1A5 receives −150 V, +100 V, +225 V and +75 V DC, and 6.3 V AC from the oscilloscope, as indicated on the Output Amplifier schematic. The +100-V and +225-V supplies are shunted together through R396 to avoid overloading of the +100-V supply by the Type 1A5 circuitry. These voltage sources are equipped with decoupling networks in the oscilloscope and in the Type 1A5. Therefore, slightly lower values will be read at the Type 1A5, as indicated by the blue figures on the Input Amplifier and the Output Amplifier schematics.

Internal Power Supplies

A +60-V supply is created within the Type 1A5 by inserting series regulator Q393 in the +100-V supply circuit. Refer to Fig. 3-3. Output DC Level (R390) adjusts the base voltage of Q393 to set the voltage at P11 terminals 1 and 3 to 67.5% of the actual value of the +100-V supply. This insures compatibility between the Type 1A5 and the oscilloscope. If the circuit requires a current increase, Q393 increases its emitter-base forward bias and the demanded current is provided. The increase in current is accompanied by a decrease in trans-resistance of Q393, allowing the power supply to maintain its 60-V level. A decrease in current demand causes the reverse effect.

A regulated +20.7-V supply (illustrated on the Input Amplifier schematic) is provided by parallel regulator transistor Q297. The base of Q297 is referenced to +20-V by Zener diode D292. This effectively clamps the emitter to +20.7-V and the resistance of Q297 is automatically regulated to maintain this level.

Current passing through Q297 develops a 6.2-V supply across Zener diode D296 in the collector circuit for activating the reed switches in the gain switching amplifier and Comparison Voltages circuits. This 6.2-V source will change with load changes when VOLTS/CM control settings are changed. R296 shunts Q297 to provide sufficient current for circuit demands.

The +20.7-V supply is returned to +75 V through 12-V relay K295 and resistor R295 when Differential Probe operation is selected. Otherwise it is returned through R294, which provides a resistance equivalent to that of the relay circuit. Differential Probe operation is selected by the PUSH ON/OFF button assembly which contains SW297. Mechanical construction of SW297 keeps it electrically connected in its last selected position. However, relay K295 is bypassed

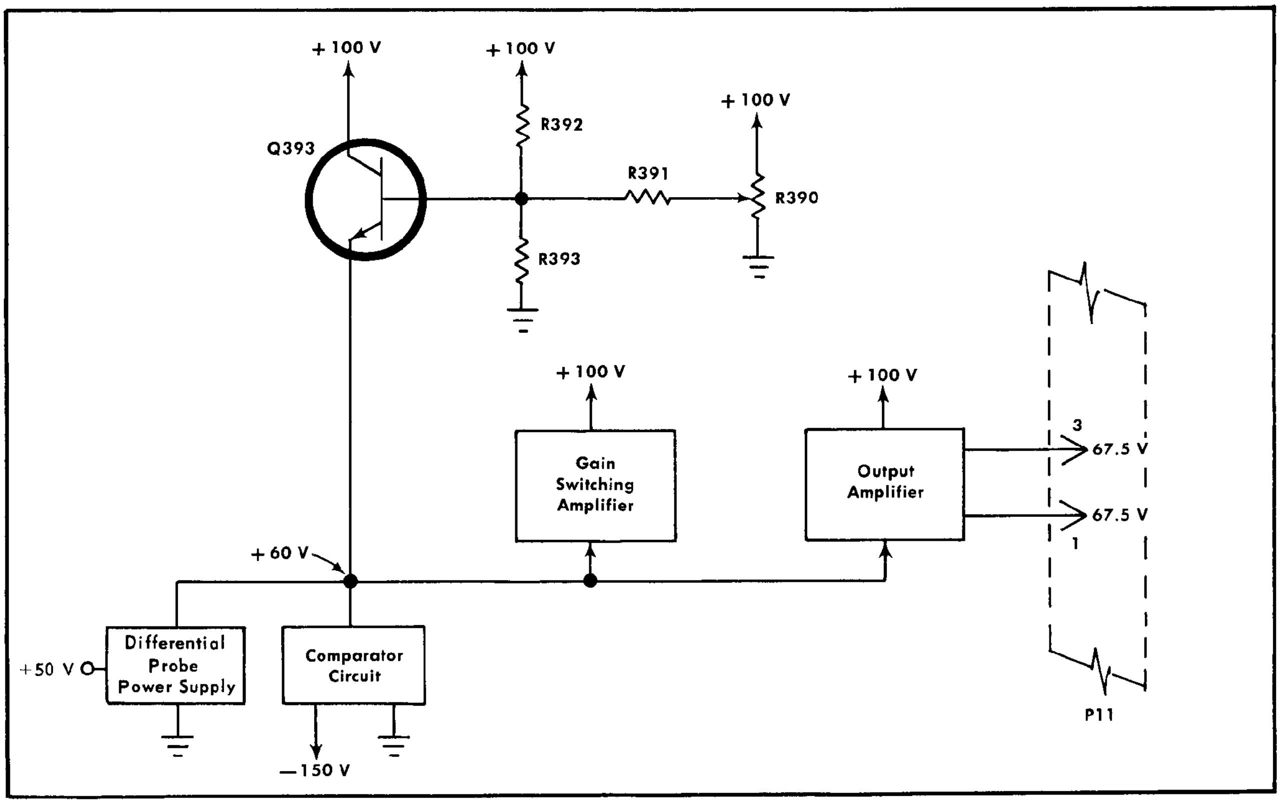


Fig. 3-3. +60 V Power Supply, simplified.

by contacts on wafer 1F of the VOLTS/CM switch whenever .5 V/CM or any less sensitive deflection factor is selected. Filaments of V164 and V264, and parallel resistor R298 use up 12 volts of the remaining voltage and the rest is dropped across R299.

Differential Probe Connector and Power Supplies

The Differential Probe connects to the Type 1A5 through 9-pin Amphenol connector J150. Push-pull signal inputs enter on terminals C and J and are routed through 93-Ω coaxial cables to the Input Amplifier board where they pass through emitter followers Q163 and Q263, are developed across R163 and R263, then connect to relay contacts K295A and B. Diodes D160 and D260 provide overload protection against negative input signals. (Protection against positive signals is a function of D167A and B, as previously explained.) When the Differential Probe is disconnected, D160 and D260 clamp the bases of Q163 and Q263 to approximately —0.6 V. R158 (PROBE STEP ATTEN BAL), R159 and R259 allow equalizing of currents to balance the two channels with the Differential Probe connected and no signal input present.

R161 and R261 are DC voltage dropping resistors used to lower the voltage applied to Q163 and Q263. At all but the lowest frequencies they are bypassed by C162 and C262. C160, R160, C260, R260, R162 and R262 improve circuit stability by damping high frequency oscillations.

The probe operates on +50-V, +20.7-V and —50-V supples provided by the Type 1A5. The —50-V supply is obtained by dropping 100 volts of the oscilloscope —150-V supply across R153. The Q153 circuit provides the regulated +50-V supply by maintaining a constant current through R154. Biasing resistors R156 and R157 set the base of Q153 to +49.4 volts. This clamps the emitters to a +50-V value. The transistor conducts about 17.85 mA of current through R154 and R155 when the probe is disconnected, or the difference between 17.85 mA and the Differential Probe +50-V supply current when the probe is connected. The constant current through R154 insures a constant load on the +60-V source to improve stability.

In the 1 through 20 mV positions of the VOLTS/CM switch, +6.2 V is routed to the Differential Probe through J150, terminal D. The +6.2 V supply is disconnected when the VOLTS/CM switch is in the 50 mV, .1 V or .2 V positions, causing the differential probe's output signal to be reduced by a factor of ten.

Resistors R151 and R152, and capacitors C151 and C152 form Differential Probe decoupling networks on the +50-V and +20.7-V supply lines.

NOTES

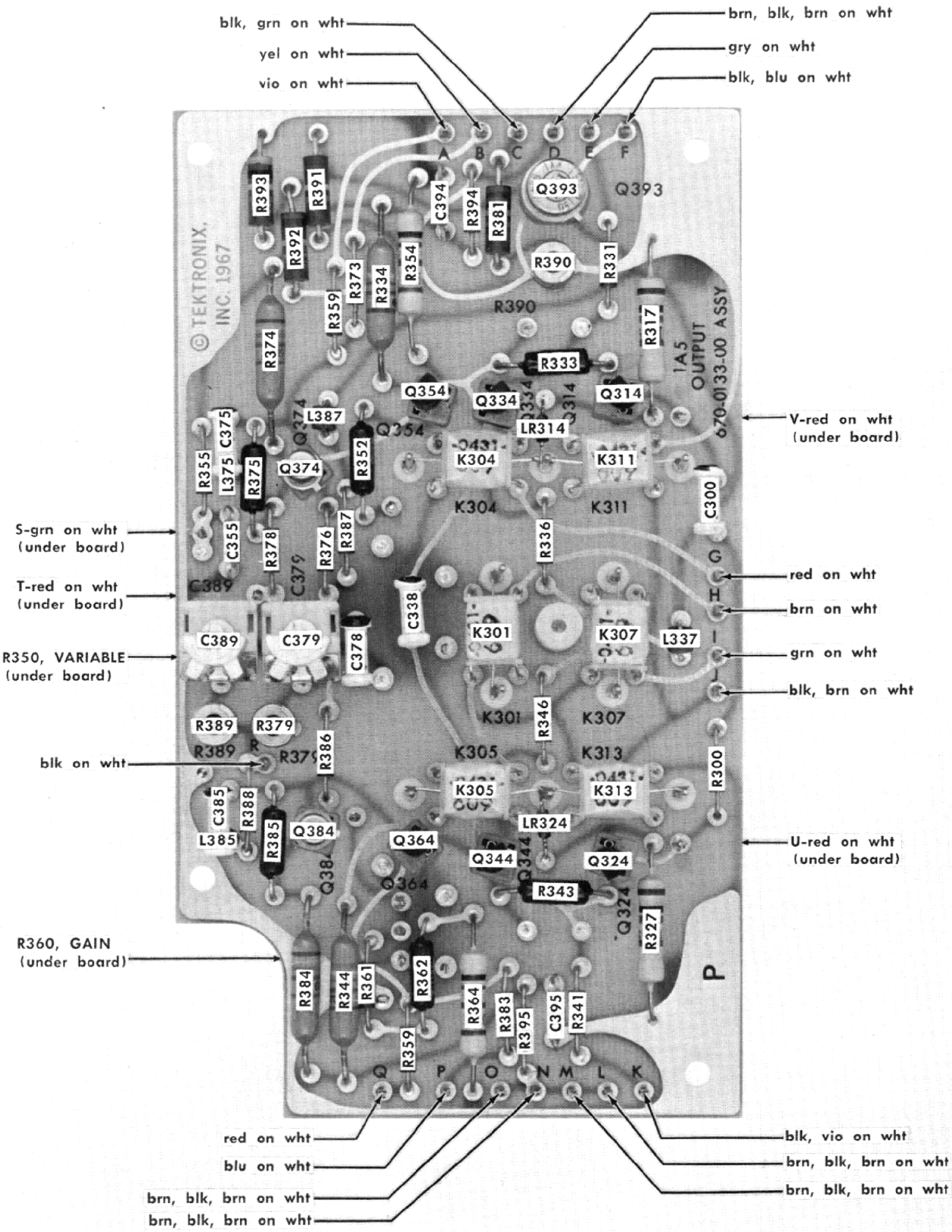
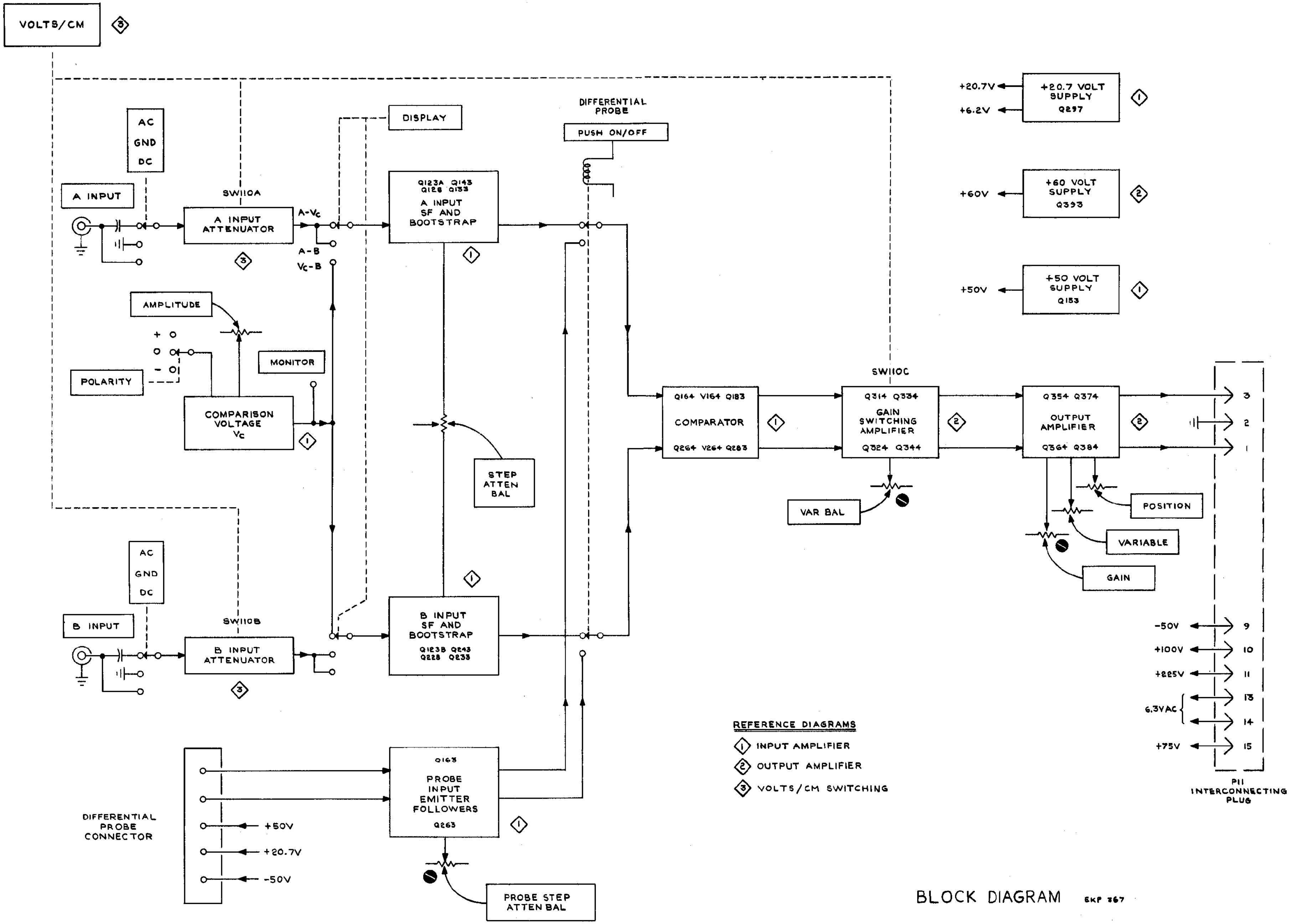
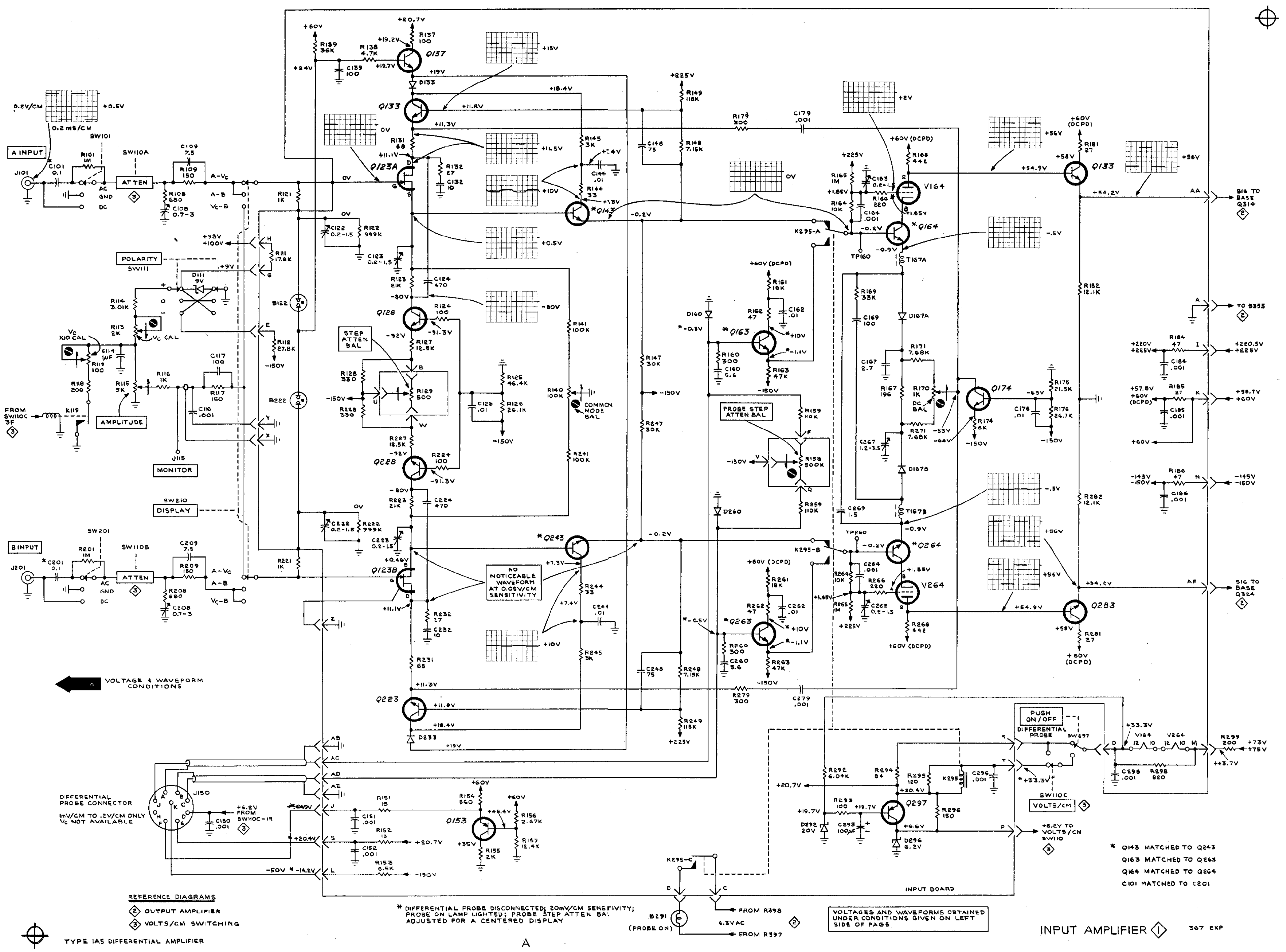


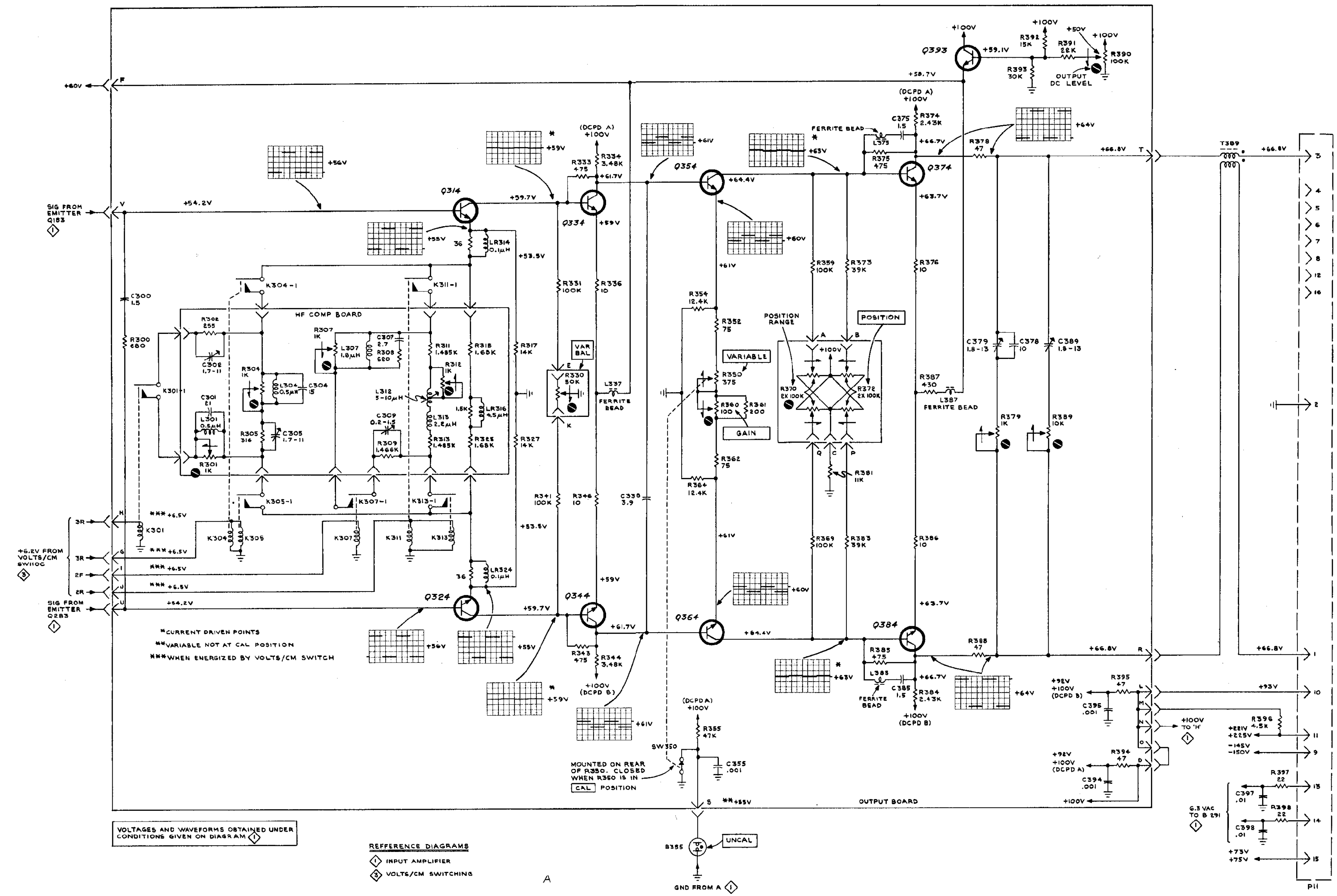
Fig. 4-7. Output Amplifier board assembly with High Frequency Compensation Component board removed.



BLOCK DIAGRAM

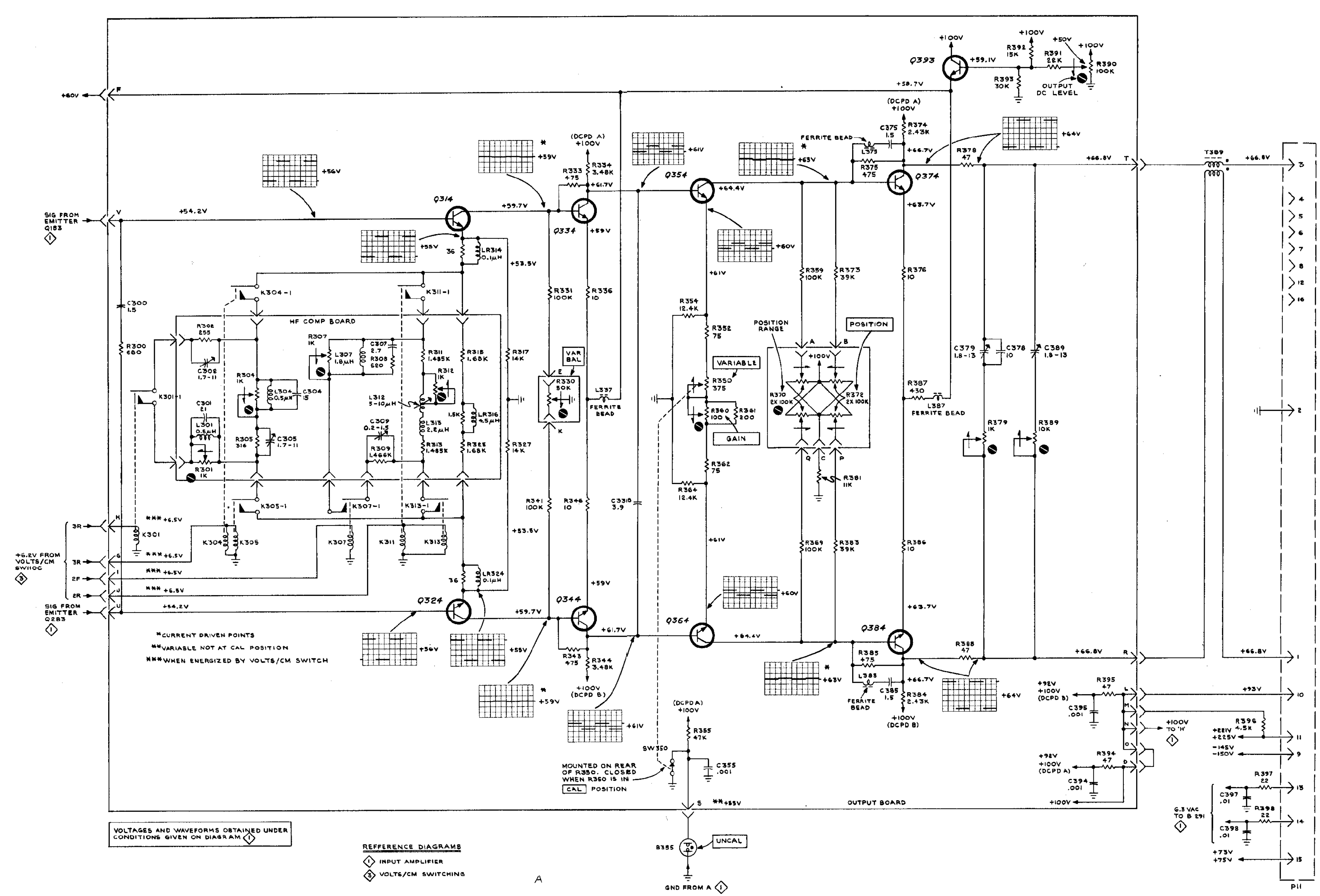
A


A INPUT
B INPUT
J101
J201
SW101
SW201
SW110A
SW110B
ATTEN
POLARITY
SW111
Vc X10 CAL
Vc CAL
AMPLITUDE
MONITOR
J115
SW210
DISPLAY
STEP ATTEN BAL
COMMON MODE BAL
PROBE STEP ATTEN BAL
DC BAL
FROM SW110C 3F
NO NOTICEABLE WAVEFORM AT 0.05V/CM SENSITIVITY
VOLTAGE & WAVEFORM CONDITIONS
0.2V/CM
0.2 mS/CM
SIG TO BASE Q314
TO B355
SIG TO BASE Q324
DIFFERENTIAL PROBE CONNECTOR
1mV/CM TO .2V/CM ONLY
Vc NOT AVAILABLE
J150
PUSH ON/OFF
DIFFERENTIAL PROBE
SW297
SW110C
VOLTS/CM
+6.2V TO VOLTS/CM SW110
INPUT BOARD
B291
(PROBE ON)
6.3VAC
FROM R398
FROM R397
* Q143 MATCHED TO Q243
Q163 MATCHED TO Q263
Q164 MATCHED TO Q264
C101 MATCHED TO C201
* DIFFERENTIAL PROBE DISCONNECTED; 20mV/CM SENSITIVITY; PROBE ON LAMP LIGHTED; PROBE STEP ATTEN BA; ADJUSTED FOR A CENTERED DISPLAY
VOLTAGES AND WAVEFORMS OBTAINED UNDER CONDITIONS GIVEN ON LEFT SIDE OF PAGE
REFERENCE DIAGRAMS
② OUTPUT AMPLIFIER
③ VOLTS/CM SWITCHING
TYPE 1A5 DIFFERENTIAL AMPLIFIER
INPUT AMPLIFIER ①
367 EKP
A



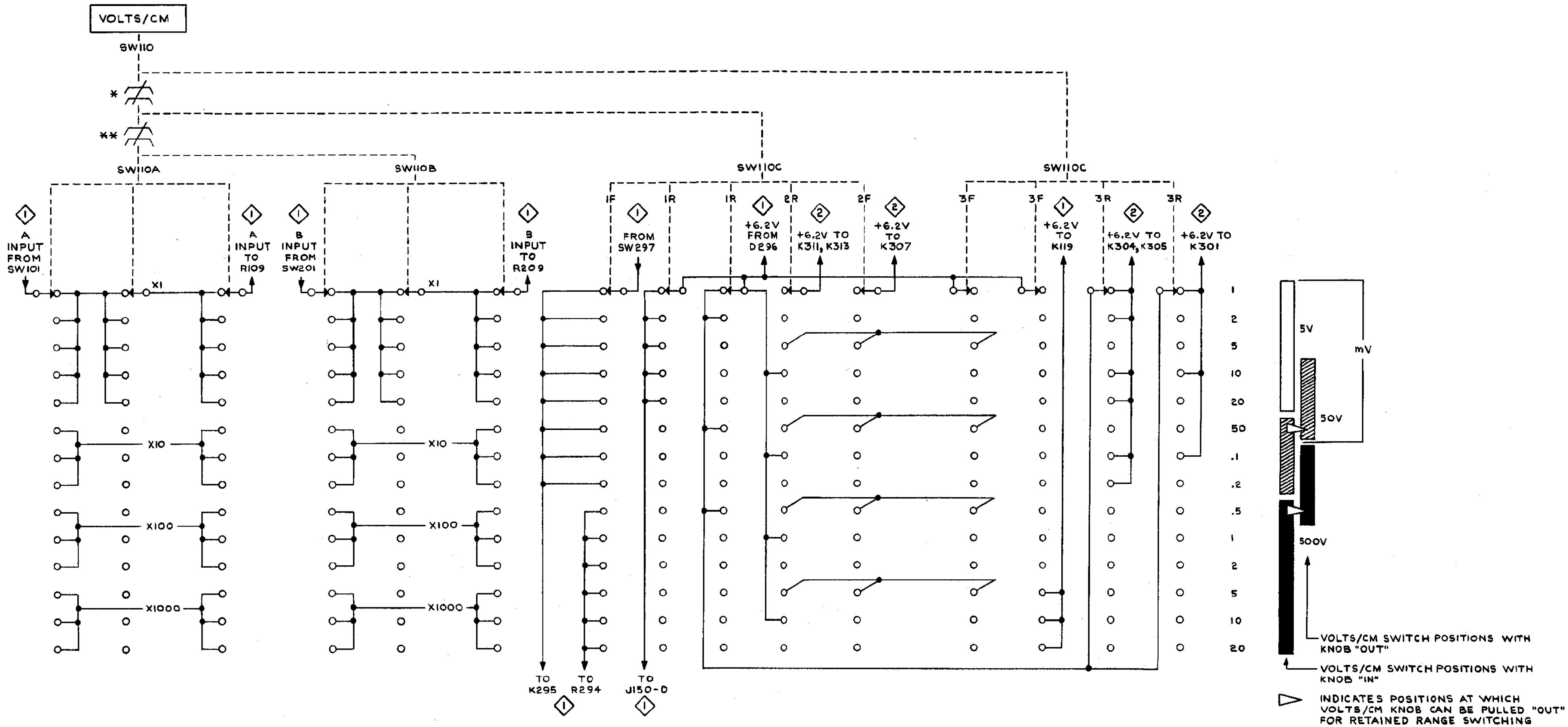
OUTPUT AMPLIFIER ② 367 EKP

TYPE 1A5 DIFFERENTIAL AMPLIFIER



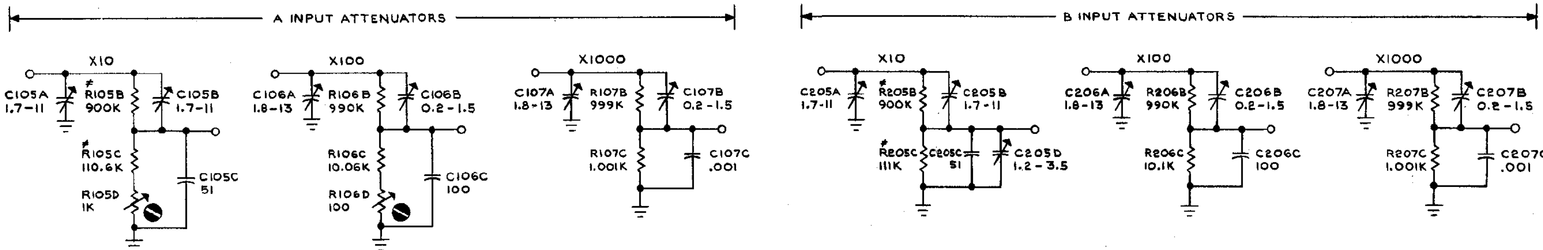
TYPE 1A5 DIFFERENTIAL AMPLIFIER

OUTPUT AMPLIFIER ② 367 EKP



* CAN BE DISCONNECTED AT 50mV AND .5V POSITIONS BY PULLING VOLTS/CM KNOB "OUT". SECTIONS 3F AND 3R OF SW110C CAN THEN BE SWITCHED 1 OR 2 POSITIONS CLOCKWISE, INDEPENDENT OF REMAINDER OF SW110 ASSEMBLY

** SW110A AND SW110B SWITCH ONLY WHEN SW110 IS SWITCHED BETWEEN 20mV AND 50mV, .2V AND .5V, OR 2V AND 5V VOLTS/CM KNOB "IN" POSITIONS



REFERENCE DIAGRAMS

(1) INPUT AMPLIFIER

(2) OUTPUT AMPLIFIER

R105B AND R205B ARE MATCHED PAIRS

R105C AND R205C ARE MATCHED PAIRS

A

TYPE 1A5 DIFFERENTIAL AMPLIFIER

VOLTS/CM SWITCHING (3)

367 EKP

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages. If it does not, your manual is correct as printed.

TYPE 1A5

SCHEMATIC CORRECTION

INPUT AMPLIFIER

CHANGE: R163 to read 47.5 k

R263 to read 47.5 k

TYPE 1A5

TEXT CORRECTION

Section 3 Circuit Description

Page 3-5, Left column, Paragraph 8
DELETE sentence beginning with "T167A".

Page 3-5, Left column, Last paragraph
CHANGE the sentence beginning with "C267" and ending with "to it" to read "C163 and C263 balance the input capacitance of the comparator stage."

Page 3-6, Left column, 2nd to last paragraph, 2nd line
DELETE "C300, R300".

Page 3-6, Right column, 1st paragraph under "Output Amplifier".
DELETE sentence starting with "L375".

Section 4 Maintenance

Page 4-10, Fig. 4-6

DELETE	Location
T167	1" above board center
C167	1" to left and below T167
C267	1" to right and below T167

Page 4-11, Fig. 4-7

DELETE	Location
C300	At right margin of board
R300	At right margin of board
C375	Near left margin of board
L375	Near left margin of board
C385	Near left margin of board
L385	Near left margin of board

Page 4-12, Fig. 4-8
DELETE R308, located near bottom right corner of board.

Section 6 Calibration

Page 6-4, Step 15
DELETE "C267"

Page 6-5

DELETE Step 3 and renumber the remaining steps accordingly.

Page 6-18, In the equipment setup for the Constant Amplitude Sine Wave Generator, CHANGE "1 MHz" to read "10 MHz".
CHANGE ".5-5 V" to read "50-500 mV".

Page 6-18

DELETE Step 15 and substitute the following in its place.

15. Adjust X1 High Frequency Common-Mode Rejection (C122, C222, C123, C223, C163, C263).

a. Equipment setup is shown in Fig. 6-17. Location of adjustments and test points are shown in Fig. 6-18.

b. Connect the two symmetrical ends of a flexible T connector to the A and B INPUTS of the Type 1A5. Connect the center of the T connector to a GR to BNC adapter (item 12). Connect the Type 191 Constant Amplitude Signal Generator (item 4) to the GR adapter, using its 5 ns GR cable.

c. Set the Constant Amplitude Signal Generator frequency to 10 MHz, the Amplitude control to 50, Variable to Cal and the Amplitude Range to 50-500 mV. (This provides 1 V into the 1 mΩ input of the Type 1A5, since no 50 Ω termination is being used.)

d. Check that the POSITION control and STEP ATTEN BAL control are at midrange and adjust R170 (Fig. 6-18) to set the trace to the center of the graticule.

e. Set the A and B Input AC-GND-DC switches to DC.

f. CHECK --- 1 cm or less display amplitude. (CMRR 1000:1 or greater)

g. ADJUST --- C122 or C222, C123 or C223, and C163 or C263 (Fig. 6-18) for minimum display amplitude. (1 cm or less vertical display amplitude for 1000:1 or greater common-mode rejection ratio.)

NOTE

Use a non-metallic screwdriver. Preset C122, C222, C123, C223, C163 and C263 so that their threads are engaged by approximately two turns. When adjusting, screw in only the one that improves common-mode rejection in each pair.

h. Change the Constant Amplitude Signal Generator frequency to 1 MHz and the Amplitude Range to .5-5 v. (This provides the 1A5 with a 10-V signal.)

TYPE 1A5

i. CHECK --- 1 cm or less vertical display amplitude. (CMRR 10,000:1 or greater)

j. REPEAT --- Steps c, g, h and i untill 1 cm or less display amplitude exists for both steps g and i.

k. Switch the VOLTS/CM control to 20 mV; simultaneously place the A and B INPUT AC-GND-DC switches to the GND position; disconnect the flexible T connector from the A and B INPUT connectors.

l. Set the oscilloscope Triggering Slope to + and repeat step 14, parts a through m; then continue with step 16.

m. INTERACTION --- Check steps 16 and 17.

Page 6-24, Step 20b
Place a period after extension. Delete the remainder of step b.

Page 6-19, Fig. 6-18
DELETE C267 and its label.

PARTS LIST CORRECTION

DELETE:

C167	281-0547-00	2.7 pF	Cer	500 V		10 %
C267	281-0076-00	1.2-3.5 pF	Air		Var	
C300, C375, C385	281-0529-00	1.5 pF	Cer	500 V		±0.25 pF
L375, L385	276-0528-00	Core, Ferramic Suppressor				
R300	315-0681-00	680 Ω			1/4 W	5 %
R308	315-0621-00	620 Ω			1/4 W	5 %
T167	120-0478-00	Toroid, 5 turns, bifilar				

CHANGE TO:

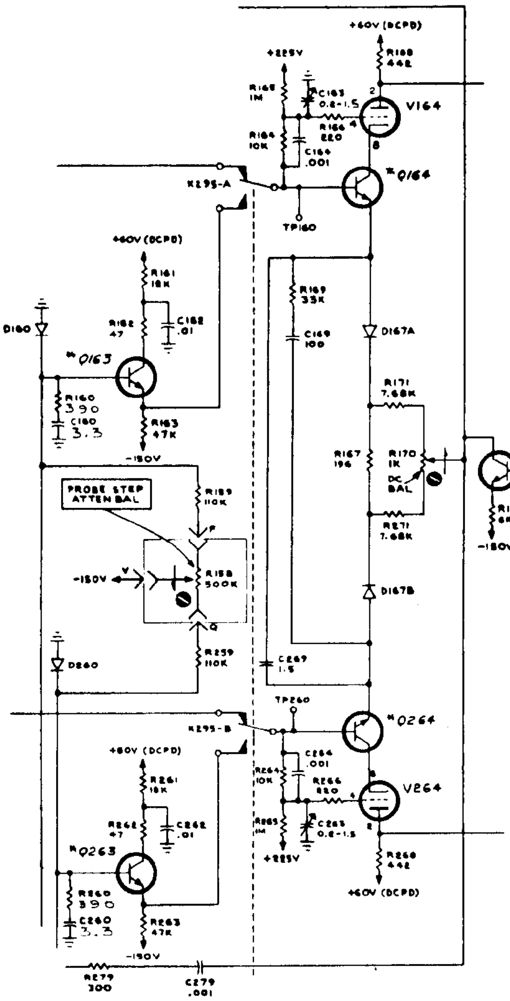
C160, C260	281-0534-00	3.3 pF	Cer			±0.25 pF
C307	281-0599-00	1 pF	Cer	200 V		±0.25 pF
L307	108-0054-00	6.4 µH				
R160, R260	315-0391-00	390 Ω			1/4 W	5 %

ADD:

C308	281-0611-00	2.7 pF	Cer	200 V		±0.25 pF

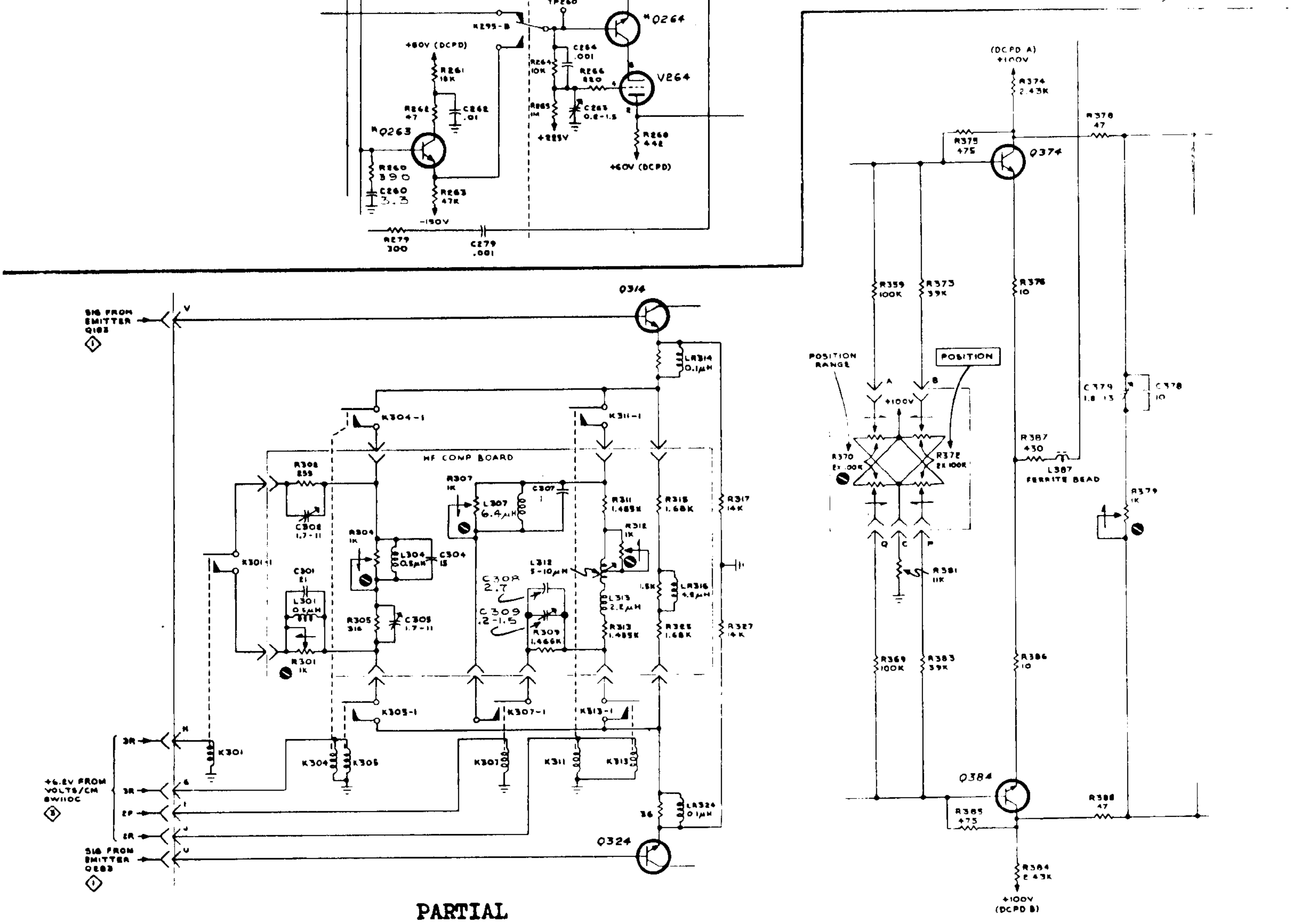
M12,495/567

SCHEMATIC CORRECTION



PARTIAL

INPUT AMPLIFIER 1



PARTIAL

OUTPUT AMPLIFIER 2

M12,495/567